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IN THE UNITED KINGDOM
FOR SERVICE IN THE UNDERDEVELOPED COUNTRIES**

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1. The Need for the Geologist.— In the less developed areas the need for geologists with a broad background and an adequate field training is among the most fundamental of technological requirements. The geologist's work is essential in the efficient search for underground water supplies and in the proper exploitation of surface water. Upon him depends the discovery of fuels - coal, oil, uranium - and the execution of prospecting programmes for mineral resources of all kinds; iron ore, the base metals, gold, platinum, the raw materials for fertilisers, even for building come within his scope. The siting of industry and the development of towns alike depend in the last analysis upon the geology.

The desirability of an exact knowledge of the bedrock and of the superficial deposits resting upon it was recognised at an early stage of the Industrial Revolution in Europe and all highly developed countries have set up permanent Geological Survey organisations, the first of its kind being the Geological Survey of Great Britain, founded by Sir Henry de la Beche in 1835. It is important to emphasise that geological work which in the long run is adequate to a nation's developing needs cannot be carried out on an ad hoc basis. The systematic mapping, on a proper scale, of the rock and drift outcrops, and the interpretation of these in terms of geological structure and history is the basis upon which all else rests. Exposure is usually such that a large element of intelligent interpretation necessarily enters into this process, and for this reason the employment of technicians without an adequate training in the science to do the field mapping is neither possible nor desirable. The work in the field needs to be supported by laboratory facilities for the study of the rocks and minerals discovered; here again, specialist training is necessary

The important place of the geologist in a developing country has been recognised by the large expansion of the United States Geological Survey in the early years of the present century, and more recently by the creation of the huge geological organisations

of the U.S.S.R., with a Minister of Geology at their head. In the overseas territories for which Britain has been responsible, Geological Surveys were set up, and these have been expanded since 1945 with financial aid from the Colonial Development and Welfare fund. A highly organised centre for research on Overseas Geology has been created in London. With the achievement of independent status the need for continued improvement of the Geological Surveys certainly becomes more, not less essential.

In the special field of metalliferous mineral deposits there are now few regions of our planet which have not been examined by prospectors. Even in the least developed areas, the obvious outcropping deposits are often known though economic factors may have delayed exploitation. Future discovery depends to an ever-increasing extent upon the application of sophisticated scientific methods. The exploitation of orebodies discovered also calls for specialised geological techniques.

2. The role of the Geophysicist.- Geological field surveying depends upon direct observation of outcrops or artificial exposures, coupled with the use of drilling. Further information about geological structure can however be obtained by the use of indirect physical measurements such as the magnetic field, the electrical properties of concealed rocks, and the gravitational attraction they exert. The geophysicist, who makes these measurements, has become an essential member of Geological Survey parties. Particular practical success has been achieved, as is now well known, in the delineation of structures favourable for petroleum accumulation, but geophysical methods have also been applied with good results to problems of water-supply, and in the search for metal deposits.

There is, then, likely to be a demand for increasing numbers of geologists and geophysicists for service in the less developed areas. The problem is, where are they to be found?

3. The United Kingdom contribution.- Since 1945 the British universities have more than doubled in size, and an increasing pace of expansion which includes the foundation of at least six new universities can be foreseen for some years to come. Geology, which has been the subject of teaching and research in the older universities from the earliest days of the science, is taught at almost all the existing institutions.

The annual output of graduates having a first degree with Honours in Geology is now of the order of 200 (vide Williams, D, 1960, p.602) while about 100 per year proceed to a postgraduate degree.

Within Great Britain there is scope for the employment of only a small proportion of this output, and as keen young men come forward, as they do, in ever increasing numbers, wishing to embrace Geology as a career, their university teachers can only tell them

that their future is likely to lie in employment overseas. Many students take up the subject with this intention. There is, indeed, a long tradition for investigation of geology in every part of the world by British-trained geologists both on behalf of governments and private enterprise.

The primary purpose of this paper is, therefore, to point out that the United Kingdom can offer a substantial contribution of trained geologists for service in the less developed areas of the world. It is worth recalling that the staff of nearly every British university geology department includes men who have served under the difficult conditions of the African forest, the arctic waste or the tropical desert, and who understand not only the technical but also the personal qualities required for success in this work.

Moreover, the British universities not only train U.K. nationals for this work, but they also welcome students from overseas. These may be supported by their governments, or by various organisations such as the British Council. Both at undergraduate and at postgraduate level, room can be found as expansion proceeds for more men from abroad, who intend to go back to their countries qualified as geologists.

It is suggested, therefore, that the present time is a particularly opportune one for the United Kingdom to assist the underdeveloped countries by providing trained British geologists, and by training their own nationals. It is clear that trained geologists are not likely to be produced in numbers adequate to meet the needs of the situation in most of the countries with which the present Conference is concerned; Britain might be said at present to possess spare capacity to meet part of the need, not only for Survey, Mining and Oil Geologists, but also for university teachers able to help in the new universities of the emergent countries.

4. Pre-University Requirements.— Admission to undergraduate status depends upon the possession of qualifications which are reasonably similar for all English universities. The normal requirement is to have passed the school examination known as the General Certificate of Education (or its equivalent) in five or six subjects, of which at least two must be at the Advanced Level. English and a language other than English must be included but for candidates wishing to enter Geology, these are usually taken at Ordinary Level. Most university geology departments prefer the Advanced Level subjects to be selected from Physics, Chemistry, Mathematics or Biology. No department (to my knowledge) requires a previous knowledge of geology, but some will accept an Advanced Level pass in the subject instead of one of four mentioned above. A good level of attainment in natural science is thus expected before entry; in Mathematics, for example, the Advanced Level requires a knowledge of the calculus as far as simple integration by parts, changes of variables and the use of partial fractions, as well as co-ordinate geometry as far as the hyperbola. In Physics, the requirements include the simple Kinetic

theory of solids, liquids and gases; a qualitative treatment of plane polarised light; refraction at a spherical interface; electrostatics and an elementary knowledge of nuclear theory. Chemistry at Advanced level covers not only systematic inorganic chemistry in the light of the periodic table, and organic chemistry as far as benzene; but also the basic facts of physical chemistry and their applications.

For admission to a post-graduate school, the normal expectation is that the candidate will possess not less than a second class honours degree or its equivalent. Many departments welcome men who have had several years professional experience after taking their first degree. Many men go to another university for their post-graduate studies and at this level, exchanges with European and American universities now take place.

5. The first degree.- In Britain the basic training of geologists for their profession is carried out while they are undergraduate candidates for the B.A. or B.Sc. degree. A minimum of three years or a maximum of four years' residence is required at this stage, depending upon the candidate's attainments at entry, and upon the general practice of the university. Usually two subjects other than geology are studied at the university to first or second year standard; at Cambridge, three subjects (of which geology is one, and mineralogy and petrology one) are read for two years to reach the Natural Sciences Tripos part I; at Oxford, on the other hand, no subject other than the main one need be read.

As already noted, no previous knowledge of geology is assumed. The early stages of the course are usually devoted to the material of which the rocks are built - that is, the rock-forming minerals - and their properties, crystal morphology, composition and identification. The use of stereograms is introduced at this stage, not only as an aid to crystallography but to induce a capacity to think in three dimensions. Geological processes are meanwhile considered, using the Principle of Uniformity as a basis of interpretation. Stratigraphy, basic to most geology, follows naturally and the small British islands offer an almost unique setting for this side of the teaching, for almost every stage from Cambrian to Cainozoic can be seen within the compass of a day's journey and four of the five Palaeozoic systems in world-wide use were named for British localities. Systematic palaeontology comes in here, with a modern emphasis on genetic studies on the one hand, and the refinement of dating by fossils on the other. The introductory mineralogy gives place to more sophisticated methods of identification; optical, x-ray, diffractometer, differential thermal analysis and meanwhile the serious study of microscopical petrography leads to theoretical petrology, with an emphasis on the application of physico-chemical and thermodynamic principles. Other work in the laboratory includes the study of geological maps, and at some universities introductory courses in geochemistry and geophysics. Lecture courses and demonstrations on the economic mineral deposits are offered by some though not all departments; there are still those who maintain that science should be pursued

for its own sake and that, in any case, a good basic training in geology is adequate to enable any problem posed by a valuable mineral deposit to be solved. There are others who find a major interest in the special problems of the search for useful minerals and therefore include extended courses on this subject in their curricula.

Meanwhile, during the vacations (which cover about five months of the year) field training is begun. The main object, apart from enabling the student to see the relationships in space of the rocks and their appearances in the field, is to teach him to record accurately on a map what he sees. The British Ordnance Survey 6-inch/mile (1:10560) maps are usually employed for base maps at this stage but some acquaintance with aerial photographs (which the geologist may expect to use as base maps in the less developed territories) is gained. At Nottingham, Imperial College London and Edinburgh special training in photogrammetry is available. Many departments subsequently allocate the student an area to map and to study in full detail as part of the work of his course, two or three months being devoted to this. Some students also avail themselves of the various opportunities offered by organisations such as I.A.S.T.E. to work in mines etc. abroad for a month or two.

The final examination covers the whole subject and usually consists of four or five theoretical papers and about 9-12 hours of practical examination. The results are classified, the system varying a little from university to university; but uniformity of standard for the first and second class is attempted by the use of external examiners from other universities.

Some students enter professional work at this stage; their age upon graduation is usually in the range 21-23; their physical stamina is often at its best and many show a contagious enthusiasm for work under difficult conditions.

6. Postgraduate degrees.— Further study in the university leads to the Master's degree, to a diploma such as the Diploma of the Imperial College (D.I.C.) of similar status to the M.Sc., or to the Ph.D. (D.Phil. at Oxford). Candidates for the two first-mentioned may be required to take formal courses of instruction in specialised branches of the subject, and the action of the Department of Scientific and Industrial Research in financing advanced Courses has led to the setting up of such courses for example, in Mining Geology and Engineering Geology at the Imperial College, London; in Applied Geophysics at Imperial College, at Birmingham and at Durham; in Geochemistry at Oxford, and in Micro-palaeontology at University College, London to mention only a few. Some original work may be required as part of the Master's degree, which takes one or two years to achieve.

For the Ph.D., the admission requirement is normally a good honours degree (i.e. Class I or high Class II); it is not essential to have taken an M.Sc. The three years residence required by most

universities for this degree is devoted to training in the methods of research, and to original investigation, working with an individual supervisor. Students are encouraged to choose their own problems; there is an increasing tendency to carry out field studies, where the these form part of the project, abroad. The prospect of employing candidates for the Ph.D. to map selected parts of the less developed territories and to bring their rocks to universities in the U.K. for laboratory study though it has sometimes been done deserves more consideration than it has so far had; it would lead to close links between university staff, students and the underdeveloped territories which could be beneficial to all the interests involved, while involving only small expenditures.

Geophysicists receive their basic training in a Geology or a Physics department, but their professional training is normally carried out at the postgraduate stage. Facilities for research exist in the Department of Geodesy and Geophysics at Cambridge; systematic practical training is provided at Imperial College, London, at Birmingham and Durham where there are, or shortly will be, sub-departments of Geophysics; the Physics department at Newcastle offers an advanced Course in Pure Geophysics, teaching and research is also carried on at Glasgow, Liverpool and in the Mining Department at Leeds. The relative emphasis on field studies as against theoretical interpretation varies among these institutions.

7. Conclusions.— (a) The United Kingdom is in a position to provide trained and experienced geologists and geophysicists for service in the less developed areas; (b) Training facilities are becoming available in Britain on an expanding scale and capacity exists to train nationals from the underdeveloped countries as well as additional U.K. personnel for this service. (c) Laboratory facilities of the most modern kind are available at the Overseas Geological Surveys centre in London, and at many of the British universities to support field work carried out in the less developed areas of the world.

8. References.

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